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PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference LEWIS LENS	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/US03/32741	International filing date *(day/month/year)* 06 November 2003 (06.11.2003)	Priority date *(day/month/year)* 06 November 2002 (06.11.2002)
International Patent Classification (IPC) or national classification and IPC IPC(7): C03B 37/14, 37/15 and US Cl.: 65/387, 393, 392		
Applicant NANOPTICS LTD		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of 15 sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☒ Non-establishment of report with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☐ Certain defects in the international application
- VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
07 June 2004 (07.06.2004)	20 September 2004 (20.09.2004)
Name and mailing address of the IPEA/US Mail Stop PCT, Attn: IPEA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (703) 305-3230	Authorized officer Steve Griffin Telephone No. 571-272-1700 DEBORAH A. THOMAS PARALEGAL SPECIALIST ~~GROUP 1300~~ Dept

Form PCT/IPEA/409 (cover sheet)(July 1998)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/US03/32741

I. Basis of the report

1. With regard to the elements of the international application:*

   ☐ the international application as originally filed.

   ☒ the description:
   pages 1-29 as originally filed
   pages NONE, filed with the demand
   pages NONE, filed with the letter of ______.

   ☒ the claims:
   pages ______, as originally filed
   pages NONE, as amended (together with any statement) under Article 19
   pages NONE, filed with the demand
   pages 30-44, filed with the letter of 08 June 2004 (08.06.2004).

   ☒ the drawings:
   pages 1-11, as originally filed
   pages NONE, filed with the demand
   pages NONE, filed with the letter of ______.

   ☐ the sequence listing part of the description:
   pages NONE, as originally filed
   pages NONE, filed with the demand
   pages NONE, filed with the letter of ______.

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
   These elements were available or furnished to this Authority in the following language ______ which is:

   ☐ the language of a translation furnished for the purposes of international search (under Rule23.1(b)).

   ☐ the language of publication of the international application (under Rule 48.3(b)).

   ☐ the language of the translation furnished for the purposes of international preliminary examination(under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   ☐ contained in the international application in printed form.

   ☐ filed together with the international application in computer readable form.

   ☐ furnished subsequently to this Authority in written form.

   ☐ furnished subsequently to this Authority in computer readable form.

   ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. ☒ The amendments have resulted in the cancellation of:

   ☐ the description, pages NONE

   ☒ the claims, Nos. 79-189

   ☐ the drawings, sheets/~~fig~~ NONE

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

** Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*
*** Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.*

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

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III. Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

1. The question whether the claimed invention appears to be novel, to involve an inventive step (to be non-obvious), or to be industrially applicable have not been and will not be examined in respect of:

☐ the entire international application,

☒ claims Nos. 1-69, 73-77

because:

☐ the said international application, or the said claim Nos. _____ relate to the following subject matter which does not require international preliminary examination *(specify)*:

☐ the description, claims or drawings *(indicate particular elements below)* or said claims Nos. _____ are so unclear that no meaningful opinion could be formed *(specify)*:

☐ the claims, or said claims Nos. _____ are so inadequately supported by the description that no meaningful opinion could be formed.

☒ no international search report has been established for said claims Nos. 1-69 and 73-77

2. A meaningful international preliminary examination cannot be carried out due to the failure of the nucleotide and/or amino acid sequence listing to comply with the standard provided for in Annex C of the Administrative Instructions:

☐ the written form has not been furnished or does not comply with the standard.

☐ the computer readable form has not been furnished or does not comply with the standard.

Form PCT/IPEA/409 (Box III) (July 1998)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/US03/32741

V. Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. STATEMENT

Novelty (N)	Claims	70-72, 78	YES
	Claims	NONE	NO
Inventive Step (IS)	Claims	70-72, 78	YES
	Claims	NONE	NO
Industrial Applicability (IA)	Claims	70-72, 78	YES
	Claims	NONE	NO

2. CITATIONS AND EXPLANATIONS

Claims 70-72 and 78 meet the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest the creation of the protrusion and then shaping it to form an optical waveguide.

Claims 70-72 and 78 meet the criteria set out in PCT Article 33(4), and thus posses industrial applicability because the subject matter claimed can be made or used in industry.

------------------ NEW CITATIONS ------------------

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the questions whether the claims are fully supported by the description, are made:

Claims 70-72 and 78 are objected to under PCT Rule 66.2(a)(v) as lacking clarity under PCT Article 6 because claims 70-72 and 78 are indefinite for the following reason(s): The preamble is directed to making a optical waveguide, but the last line refers to an optical element. One of ordinary skill would be confused as to whether they are the same things, or if they can be different. In claim 72, the claim is inaccurate because a shape cannot define a refractive index; refractive index is completely independent of shape - one would not know what is meant by this. Claim 72 there is no antecedent basis for "the near field". It is unclear if the shaping of claim 72 is in addition to the shaping of claim 70 - or if it further limits it. Claim 78: there is no antecedent basis for "the motion" and "the imaging devices".

What is claimed:

1. A method and a device in which arbitrary micro and/or nano structures are produced at the end of an optical fiber or hollow fiber or low index waveguide or high index waveguide or other such geometry for modulating a light beam transmitted through the fiber or other waveguide in a procedure that uses a theoretical simulation of the light modulating parameters based on an exact numerical field calculation inside and beyond the end of the fiber or waveguide, a method of production of the simulated micro and/or nano optical structure by a combination of technologies that produces the optical element without or with tapering using pulling and/or mechanical and/or laser polishing and/or heating, with and/or without etching and/or writing and/or masking with or without imposed radiation and with or without photoresist and/or other similar procedures and/or imprinting and/or molding and/or deposition depending on the parameters of the micro and or nano optical structure that has to be achieved and this combination of fabrication techniques being guided by integrated simulation and a characterization tool that is a critical part of the process which allows highly accurate geometric and light profiling of the micro and/or nano optical structure at the surface, in the near-field or at specific distances above the micro and/or nano optical structure with little contribution from out-of-focus light so that the phase properties of the wavefront can accurately be characterized in a way that is totally integrated with atomic force topographic imaging and/or other scanned probe methods (SPM) for micro and or nanoscopic characterization and/or with light wave measurements such as return loss, polarization dependent loss, coupling efficiency and other similar parameters and that these methods are also totally integrated with far-field optical characterization and this integration of the simulation, production and characterization is a realization that near-field optics within this context of integrated characterization, simulation and production is the critical missing link that facilitates such multistep procedures for optical element production.

2. A method and a device as in claim 1 that integrates between theory, characterization methodology and integrated production methodologies that allow for the control of fabrication and the generation of structures that could not be fabricated or whose fabrication could not be controlled before the realization of such integrated and interconnected methodologies of simulation, production and characterization that

had not been applied to guide the fabrication techniques of micro and/or nano optical components before the inventive steps of this patent.

3. A method and a device as in claim 1 and 2 for the fabrication of micro and/or nano optical structures that requires the accurate characterization of mode field diameters or spot sizes at distances that are relatively short compared with conventional far-field optics in order to overlap such mode field diameters between a fiber with an integral optical element and another optical device that needs to be coupled to the integral fiber optical element or other optical device with high coupling efficiencies.

4. A method and a device in claims 1-3 for the production of integral fiber and other micro and/or nano optical structures in which far-field measurements and/or paraxial approximation based simulations do not provide the necessary information to guide the fabrication of the lens and all of its parameters.

5. A method and a device as in claims 1-4 that presents a solution for the first time based on the application of near-field optical tool in the problem of simulation and production of the waveguide including fiber integral micro and/or nano optical structure which has prevented previous inventions from achieving the accuracies required for miniaturized optical components because of the lack of a near-field optical characterization tool in the iterative loop of production and/or exact numerical field simulation that guides the fabrication in the current invention.

6. A method and a device as in claims 1-5 that presents the first solution of the integral fiber and other micro and/or nano optical structure problem in which the theory allows for an exact numerical field calculation inside and outside the integral fiber or other micro and/or nano optical structure that permits an analysis in terms of coupling efficiency, beam waist diameter, working distance taper angle, radius of curvature and other such parameters and thus, the theory becomes a tool for designing an optimal integral fiber or other micro and/or nano optical structure and the coupling between these structures.

7. A method and a device as in claims 1-6 in which the combination of theoretical simulation, near-field optical and its associated methodologies and the iterative

guiding of the combination of production techniques allows for high efficiency coupling.

8. A method and a device as in claims 1-7 in which the core has a conical shape with the angle determined by the taper angle and the core to cladding diameter ratio with the interface between cladding and air considered to have a hyperbolic shape with this shape described by two parameters which are the asymptotic angle and the radius of curvature at the height of the hyperbola where the asymptotic angle is assumed to be the same as the taper angle.

9. A method and a device based on claims 1-8 that allows micro-optical structures that were unable to be achieved previously with waist diameters that are less than 3 microns including in cases where, for wavelengths of 1.5 μ, waist diameters of 1.6 μ are achievable and that such structures allow for large coupling efficiencies over 80 % for waist diameters between 2 and 3 microns and over 90 % for waist diameters above 3 microns.

10. A method and a device as in claim 1-7 for the fabrication of other components that can achieve other micro and/or nano optical spatial and temporal modulation as integral or not integral devices to fibers, waveguides or other optical structures including mode convertors, couplers, multi lens arrays and other solutions such as microelectromechanical devices in glass or other materials that will not be able to achieve their desired results without the integration of the simulations and the characterization that are an essential part of this invention as described in claim 1-7.

11. A method and a device as in claim 1-10 based on field calculations utilizing a finite element method for numerical solution of partial differential equations that realizes that this is critical component in simulations of the devices in claims 1-10, where the fabrication parameters are monitored experimentally with near-field optics integrated with far-field optical characterization and with atomic force imaging and other scanned probe methods and the theoretical constraints are adjusted based on the

results of the experimental measurement where these aspects of the invention allow for multi procedure production methodologies.

12. A method and a device as in claims 1-7, 10 and 11 in which the theory allows us to predict the parameters of the fiber lens or other micro and/or nano optical structure that for a given waist diameter will give maximum coupling efficiency.

13. A method and a device using a combination of claims 1-12 in which the theory allows us to predict the parameters of the fiber lens or other micro and/or nano optical structure that for a given waist diameter will give maximum coupling efficiency.

14. A method and a device as in claims 1-7, 10 and 11 in which near-field optical measurements allow us to practically confirm the theoretical predictions and allow for hand in hand characterization of fiber lens and other micro and/or nano structure fabrication methods.

15. A method and a device using a combination of claims 1-13 in which near-field optical measurements allow us to practically confirm the theoretical predictions and allow for hand in hand characterization of fiber lens and other micro and/or nano structure fabrication methods.

16. A method and a device as in claims 1-7,10 and 11 in which a methodology of theoretical simulations with adjusted boundary conditions iteratively defined by near-field optics and its associated measurement techniques allows for the availability of exact field calculations as an effective method for design of micro and nano optical elements in which the general far-field optical approximations partially or completely fail and for which near field and associated measurement of the field emerged from the fiber lens is the only reliable method for its characterization and for which the generally used far-field characterization methodologies are not valid for the components described in this patent.

17. A method and a device using a combination of claims 1-15 in which a methodology of theoretical simulations with adjusted boundary conditions iteratively

defined by near-field optics and its associated measurement techniques allows for the availability of exact field calculations as an effective method for design of micro and nano optical elements in which the general far-field optical approximations partially or completely fail and for which near field and associated measurement of the field emerged from the fiber lens is the only reliable method for its characterization and for which the generally used far-field characterization methodologies are not valid for the components described in this patent.

18. A method and a device as in claims 1-7, 10, 11 which allows for a synergistic integrated interaction producing a coordinated interplay of parameters with what has been considered to be alternate technologies in fiber lens formation and/or have never been used in fiber/waveguide lens formation and these alternate technologies include the production of optical elements without or with tapering using pulling and/or mechanical and/or laser polishing and/or heating, with and/or without etching and/or writing and/or masking with or without imposed radiation and with or without photoresist and/or other similar procedures and/or imprinting depending on the parameters of the micro and or nano optical structure that has to be achieved.

19. A method and a device using a combination of claims 1-17 which allows for a synergistic integrated interaction producing a coordinated interplay of parameters with what has been considered to be alternate technologies in fiber lens formation and/or have never been used in fiber/waveguide lens formation and these alternate technologies include the production of optical elements without or with tapering using pulling and/or mechanical and/or laser polishing and/or heating, with and/or without etching and/or writing and/or masking with or without imposed radiation and with or without photoresist and/or other similar procedures and/or imprinting depending on the parameters of the micro and or nano optical structure that has to be achieved.

20. A method and a device as in claims 1-7, 10 and11 in which it is realized that, together with theoretical simulation, the application of the near-field in a way that is totally integrated with atomic force topographic imaging and/or other scanned probe methods (SPM) for micro and or nanoscopic characterization and other similar parameters and that these methods are also totally integrated with far-field optical characterization and this integration of the simulation, production and characterization

is a realization that near-field optics is critical to not only choose the parameters of the use of each of the production technologies but also to choose the selection and the order in which the production technologies could be used to achieve a specific result in order to provide not only the type of light distribution in the specific regions required but also to obtain registered super-resolution topographic and on-line far-field measurements and other parameters such as return loss, polarization loss, coupling efficiency or other similar parameters that is crucial to producing the highly accurate lens structures with high centration, coupling efficiency and other related optical parameters.

21. A method and a device using a combination of claims 1-19 in which it is realized that, together with theoretical simulation, the application of the near-field in a way that is totally integrated with atomic force topographic imaging and/or other scanned probe methods (SPM) for micro and or nanoscopic characterization and other similar parameters and that these methods are also totally integrated with far-field optical characterization and this integration of the simulation, production and characterization is a realization that near-field optics is critical to not only choose the parameters of the use of each of the production technologies but also to choose the selection and the order in which the production technologies could be used to achieve a specific result in order to provide not only the type of light distribution in the specific regions required but also to obtain registered super-resolution topographic and on-line far-field measurements and other parameters such as return loss, polarization loss, coupling efficiency or other similar parameters that is crucial to producing the highly accurate lens structures with high centration, coupling efficiency and other related optical parameters.

22. A method and a device in which a near-field optical aperture, can be as small as 1/10 the wavelength of light in order to accept light from a very wide angle and this means that the light that is collected only at the aperture has enough fluence to be detectable and the light that is collected by such an aperture is not contaminated by out-of-focus light that can be as close as 1/10 th the wavelength of light away from the aperture and when this is added to the fact that the aperture acts as a coherent point source of collection one can see that monitoring the distribution of light with such a small near-field aperture in the far-field allows for the monitoring of a coherent

wavefront and if such light is monitored at several optical planes around the focus and/or away from the focus of say a lens or other optical device that is being investigated then one can determine, by interaction with theoretical simulations, the phase properties with high accuracy of the optical system being investigated.

23. A method and a device as in claim 22 in which the near-field optical technique obtains the intensity information not only without lens based distortions but also without any out-of-focus contribution and in which the near-field optical methodology of the light distribution in one or more optical planes is a true measure of the intensity at different z sections.

24. A method and a device as in claim 23 in which in such a methodology one can consider combining the near-field optical information at certain points with the lens based information to obtain rapid analysis of the phase properties at resolutions much better than can be obtained with lens based techniques for refractive index, phase distrbution and other phase based properties.

25. A method and a device as in claims 22-24 applied in general to problems of coherent collection of light without regard to the type of sample or problem under investigation.

26. A method and a device as in claims 22-25 in which it is realized that the combination of near-field characterization integrated with far-field optical characterization and with atomic force imaging and other scanned probe methods allows even for standard far-field techniques for phase and refractive index measurement such as differential interference contrast to be considerably improved with such corrections and improvements, not to exclude others, as the determination of surface topography, and/or slope, and/or the point spread function with near-field optical aperture and/or apertures and/or nanometer obscuring with nanoparticles in differential interference contrast in order to remove artifacts and improve resolution using these and other characteristics of scanned probe microscopy that allow the phase and refractive index properties to be accurately measured with small or no errors.

27. A method and a device in which it is realized that the near-field optical element can be combined with fiber couplers and similar element in order to allow mixing of collected light that is illuminating the device under test in order to investigate phase properties also in the manner of a fiber interferometer with one of the arms being a near-field optical device.

28. A method and a device as in claim 26 in which a combination of the near-field optical device is used to provide a point or multiple point sources of a stable source of light for the point spread function (PSF) of the far-field optical imaging system which can be based on confocal differential interference contrast or differential interference contrast with charge coupled device or other wide field or point imaging where such knowledge of the PSF is crucial to the high accuracy of the index of refraction that is needed for the full characterization of the devices that are part of this patent.

29. A method and a device as in claim 28 in which the point spread function can be obtained with the device under test in place.

30. A method and a device as in claim 29 in which the sample under test contributes significantly to the point spread function and can alter the point spread function at different locations in the sample so multiple measurements of the point spread function at different locations on the sample may be needed for full theoretical analysis of the results.

31. A method and a device as in claim 26-30 in which it is realized that glass-pulling or molding with glass or plastic technology or other technologies that can produce a near-field aperture allows for the production of unique point sources that can add singular information on the optical properties of the far-field microscope especially for differential interference contrast where one such structure, not to exclude other structures, would be the ability to produce a near-field optical element with two tapered fibers in order to deliver to the microscope two beams of controlled polarization and known shear vector and thus allowing for a true differential interference contrast point spread function which is important for achieving the highest accuracy in index of refraction measurements.

32. A method and a device as in claim 31 in which such structures allow for these near-field element based points of light to be present on the optical axis without obstruction from the integral atomic force cantilever that keeps the point of light with extremely high stability relative to the sample being investigated using atomic force feedback.

33. A method and a device as in claims 25-32 in which it is realized that a differential interference contrast measurement can be vastly improved by the controlled positioning with, for example, an atomic force sensor of a particle or other tip that either alters locally and/or nanometrically the differential interference contrast image at one position and then at another position to improve resolution.

34. A method and a device as in claim 33 where the controlled positioning is defined a number of times and the result, together with the exact 3D position from the atomic force sensor, being used as a constraint for the theoretical calculations outlined above to define the optical properties of the device under test including the 3D phase image which is an accurate representation of the refractive index in 3D.

35. A method and a device in which one can use any conventional far-field imaging system with or without differential interference contrast and simply block at certain controlled nanometric or micrometric positions the rays of light reaching a detector in transmission or reflection mode to improve resolution.

36. A method and a device as in claim 29 in which the information from such nanometric or micrometric obstruction, together with the exact 3D position from the atomic force sensor, can be used as a constraint with the calculations to deconvolve high resolution images of the device under test.

37. A method and a device as in claims 22-36 in which highly accurate 3D representations of refractive index is used to characterize embedded waveguides and waveguides that are not embedded with and/or without the passing through the waveguide of radiation in and/or out of the absorption of the waveguide and with cw and/or pulsed lasers including ultrafast femtosecond and attosecond lasers in which

some property such as the refractive index of the waveguide is altered by the passage of the radiation and is detected either by a linear or non-linear optical phenomenon.

38. A method and a device based on a combination of claims 22-36 in which highly accurate 3D representations of refractive index is used to characterize embedded waveguides and waveguides that are not embedded with and/or without the passing through the waveguide of radiation in and/or out of the absorption of the waveguide and with cw and/or pulsed lasers including ultrafast femtosecond and attosecond lasers in which some property such as the refractive index of the waveguide is altered by the passage of the radiation and is detected either by a linear or non-linear optical phenomenon.

39. A method and a device in which linear or non-linear optical phenomena are used to monitor the passage of radiation through a waveguide in which the alteration by the presence of the radiation is not the refractive index.

40. A method and a device in which the refractive index is being measured while a laser or some other method is used to change the refractive index in the medium to create a waveguide and this is being guided in an interative fashion by the measurement of refractive index.

41. A method and a device in which local heating in a waveguide is used to measure and to image the passage of light in a waveguide.

42. A method and a device in which local heating in a waveguide is used to measure and to image the passage of light in a waveguide using a method of scanned probe microscopy that can be either perform thermal conductivity or point thermocouple measurements.

43. A method and device in which nanometric blocking is used together with differences in intensity when the probe either blocks or does not block the rays of the far-field imaging system from the position on the sample to improve resolution.

44. A method and device as in claim 43 which can be extended to any technique that uses optical, or electron optical or ion optical imaging such as for example confocal Raman microspectroscopy and which in some cases where these methodologies can be combined with evanescent wave illumination instead of the conventional illumination that is present in all far-field optical microscopes and in which the use of an atomic force sensor directly correlated pixel for pixel with the optical imaging allows a very strict delineation of the surface of the sample which is used as a powerful constraint for the theoretical calculations.

45. A method and a device as in claims 22-44 in which it is realized that iterative procedures of simulation, production and characterization with these techniques can use the data so obtained in order to arrive at profiles of the refractive index of the device under test and which in the above case, in which the phase properties are defined, the distribution of the refractive index can be used as a parameter that can be minimized mathematically to give the best integrated solution using claims 1-7, 10 11.

46. A method and a device for micro and/or nano optical structure characterization in which it is realized that near-field optics in reflection or transmission mode is also capable of refractive index information since the reflection or transmission from a device under test illuminated by a near-field optical element can give the index of refraction relative to a known refractive index.

47. A method and a device as in claims 22-46 that can be used in combination with claims 1-7, 10 and 11.

48. A method and a device based on a combination of claims 1-47.

49. A method and a device that uses the integrated procedures of simulations, production and characterizations as in claims 1-7, 10 and 11 and/or claims 47 and 48 that leads to new horizons in such lens fiber production and permits structures to be produced that could not be produced or produced with high tolerance that is based on tapering the cladding and the waist diameter being based on the radius of curvature and the tapering angle that is achieved by polishing or etching.

50. A method and a device that uses the integrated procedures of simulations, production and characterizations based on a combination of claims 1-49 that leads to new horizons in such lens fiber production and permits structures to be produced that could not be produced or produced with high tolerance that is based on tapering the cladding and the waist diameter being based on the radius of curvature and the tapering angle that is achieved by polishing or etching.

51. A method and a device as in claims 49 and/or 50 such that the simulations and characterization allow tapering the fiber such that the cladding and the core are tapered and then using etching or polishing to simply alter the cladding and not the core thus permiting an additional degree of freedom so that the fiber lens parameters depend now on the taper angle of the core, taper angle of the cladding, which is now independent of the core taper angle and the radius of curvature of the cladding and thus, allowing for many advantages including the reduction of the waist diameter to be less 3.5 microns and allowing for large coupling efficiencies to be achieved greater than 80 % between an appropriate device.

52. A method and a device as in claims 49 and/or 50 in which ultrasmall diameters can be achieved with a control of the focal spot to a diameter of 0.25 microns in the wavelength regime of interest to the telecommunication industry between 1.3 and 1.6 microns something which has been impossible to previously achieve even for larger spot sizes.

53. A method and a device as in claims 49-52 in which the tapering of the fiber is done under laser heating with defined tension and defined cooling so that in order to achieve the characteristics needed for this goal the heat has to be kept at a minimum while the tension is kept at a maximum with a cooling that has to be optimally controlled based on the results of the near-field optical characterization and its associated methodologies and the iterative theoretical simulations and realizing that the pulling gives a specific angle of taper to the fiber tip so that this can control the waist diameter to a level of $\pm$ 0.25 microns depending on the exact characteristics of the taper and this needs to be accurately simulated and characterized together with the waist diameter of the beam and these parameters can be measured by near-field optics and its associated techniques in this loop of iteration that are a critical part of the

process of lens formation, which for small spot sizes cannot maintain in the far-field Gaussian characteristics in spite of the fact that the tools in this patent are used to maintain the near-field distribution so that the mode field diameters of the input and output device overlap.

54. A method and a device as in claims 1-7, 10 and 11 and/or claims 47 and 48 in which the spot size is not only related to the cone angle but is also related to the separation between the end of the fiber and the position to which the core extends and with such controls now exercisable it is possible to modulate the geometry and the nature of the laser-heating phase at the tip after the tapering with tension, heating and cooling and where coupling efficiencies of >80 % can be achieved for a variety of lens parameters with fine control.

55. A method and a device based on a combination of claims 1-53 in which the spot size is not only related to the cone angle but is also related to the separation between the end of the fiber and the position to which the core extends and with such controls now exercisable it is possible to modulate the geometry and the nature of the laser-heating phase at the tip after the tapering with tension, heating and cooling and where coupling efficiencies of >80 % can be achieved for a variety of lens parameters with fine control.

56. A method and a device in which for fiber lens production there is great importance placed on the protrusion that can be produced as a result of the pulling with tension, heating and cooling and where the defined protrusion in the center of the fiber or waveguide has to be controlled depending on the parameters of the lens as characterized by the techniques as in claims 1-7, 10 and 11 and/or claims 47 and 48.

57. A method and a device in which for fiber lens production there is great importance placed on the protrusion that can be produced as a result of the pulling with tension, heating and cooling and where the defined protrusion in the center of the fiber or waveguide has to be controlled depending on the parameters of the lens as characterized by the techniques based on a combination of claims 1-49.

58. A method and a device as in claim 56 and/or 57 in which the protrusion allows us to control the centration and this has been discovered as a parameter of crucial importance in such fiber lens formation only because of the characterization and simulation tools that have been used in this production.

59. A method and a device as in claims 58 in which the protrusion is subsequently removed to define distances with controlled etching as defined by the characterization with for example 30 minutes needed to produce a geometry that modulates the curvature of the protrusion and that subsequent laser or other melting is used to achieve the final parameters of the lens as defined by the near-field optical results.

60. A method and a device as in claims 1-7, 10 and 11 and/or claims 47 and 48 in which lensing can be achieved with high accuracy of the lens position to the point where the fiber that can be stripped with extreme accuracy of a few tenths of a micron using laser ablation of the stripped fiber with deep ultraviolet lasers.

61. A method and a device based on a combination of claims 1-59 in which lensing can be achieved with high accuracy of the lens position to the point where the fiber that can be stripped with extreme accuracy of a few tenths of a micron using laser ablation of the stripped fiber with deep ultraviolet lasers.

62. A method and a device as in claims 1-7, 10 and 11 and/or claims 47 and 48 in which cantilevering of the fiber can be achieved to direct the light at an angle relative to the direction of the main length of fiber with one set of parameters for fiber bending of angles that can be varied from 90° to 0 ° (i.e. no bending).

63. A method and a device using a combination of claims 1-61 in which cantilevering of the fiber can be achieved to direct the light at an angle relative to the direction of the main length of fiber with one set of parameters for fiber bending of angles that can be varied from 90 ° to 0 ° (i.e. no bending).

64. A method and a device as in claims 1-7, 10 and 11 and/or claims 47 and 48 in which it is possible to use a combination of the techniques described above to achieve tapering with polishing and lensing at ninety degrees to the fiber axis.

65. A method and a device using a combination of claims 1-63 in which it is possible to use a combination of the techniques described above to achieve tapering with polishing and lensing at ninety degrees to the fiber axis.

66. A method and a device as in claims 64 and/or 65 in which a appropriate coating is used to produce a beam splitter by coating a mechanical and/or a laser polished lens on one face only and/or by producing an elliptical structure on one side of a polished lens.

67. A method and a device as in claims 1-7, 10 and 11 and/or claims 47 and 48 in which the formation of a cylindrical lens is achieved.

68 A method and a device based on a combination of claims 1-66 in which the formation of a cylindrical lens is achieved.

69. A method and a device as in claims 67 and/or 68 in which the lens made by the above procedure is subsequently polished from two sides (180^0) from one another and then another laser step is introduced to smooth the rough polished surface to achieve the control and optical quality that is desired and with such a combined procedure it is possible to achieve a ratio of the elliptical axes of at least 1:3.

70. A method and a device as in claims 1-7, 10 and 11 and/or claims 47 and 48 in which lenses can be made with preservation of the polarization from a polarization preserving fiber.

71. A method and a device based on a combination of claims 1-69 in which lenses can be made with preservation of the polarization from a polarization preserving fiber.

72. A method and a device as in claims 1-7, 10 and 11 and/or claims 47 and 48 in which polarization can be achieved through a lens without the use of polarization preserving fibers.

73. A method and a device based on a combination of claims 1-71 in which polarization can be achieved through a lens without the use of polarization preserving fibers.

74. A method and a device as in claims 1-7, 10 and 11 and/or claims 47 and 48 in which the deposition of metals on the stripped fiber for soldering and other requirements including magnetic attraction can be achieved with high accuracy relative to such fiber lenses both in terms of vacuum deposition and electrochemical and electroless depositions if the criticality of the characterization described above is applied in a closed loop to such fiber lens metallization so that hermetic seals to various packaging by combination with electrochemical deposition and the galvana plastic deposition of materials such that the material is deposited in a plastic form or the materials can be deposited in 3D using soft lithography techniques or controlled vacuum techniques with rotation with the resulting structures capable of being laser welded.

75. A method and a device based on a combination of claims 1-71 in which the deposition of metals on the stripped fiber for soldering and other requirements including magnetic attraction can be achieved with high accuracy relative to such fiber lenses both in terms of vacuum deposition and electrochemical and electroless depositions if the criticality of the characterization described above is applied in a closed loop to such fiber lens metallization so that hermetic seals to various packaging by combination with electrochemical deposition and the galvana plastic deposition of materials such that the material is deposited in a plastic form or the materials can be deposited in 3D using soft lithography techniques or controlled vacuum techniques with rotation with the resulting structures capable of being laser welded.

76. A method and a device as in claims 1-7, 10 and 11 and/or claims 47 and 48 in which the procedures are used for other waveguide structures including those that can be microfabricated with silicon by the alteration in the refractive index of silicon by doping or other means.

77. A method and a device based on a combination of claims 1-75 in which the procedures are used for other waveguide structures including those that can be

microfabricated with silicon by the alteration in the refractive index of silicon by doping or other means.

78. A method and a device as in claims 1-7, 10 and 11 and/or claims 47 and 48 in which the metal depositions can completely cover the lensed or the unlensed fiber tip or waveguides so that an aperture or apertures can be formed on these structures by coating the device fully with metal and then dipping the fiber tip in a solution that will deposit a resin or other viscous solution on the surface such that at the lens because of its anglès and interactions is not coated with the viscous solution and so a small region of the metal coating can be exposed and etched allowing for the coating to be in close proximity to the lens preventing subsequent problems such as vibrations and other mechanical or similar problems.

79. A method and a device based on a combination of 1-77 in which the metal depositions can completely cover the lensed or the unlensed fiber tip or waveguides so that an aperture or apertures can be formed on these structures by coating the device fully with metal and then dipping the fiber tip in a solution that will deposit a resin or other viscous solution on the surface such that at the lens because of its angles and interactions is not coated with the viscous solution and so a small region of the metal coating can be exposed and etched allowing for the coating to be in close proximity to the lens preventing subsequent problems such as vibrations and other mechanical or similar problems.

80. A method and a device in which the process of nanoindentation can be used to create a nanodimension opening at the tip and/or the side and/or any desired point of a tapered and/or coated and/or other structure such as a fiber or other waveguide.

81. A method and a device as in claims 80 in which the resulting structures can be controlled in terms of their optical output in an iterative way if the structure of the fiber aperture during production is complexed with a light input and the light output is monitored in terms of intensity and/or distribution.

82. A method and a device which will permit automation of aperture formation using nanoindentation procedures or other procedures that could produce nano openings in a

metal or other opaque coatings and such nanoindentation methodologies could include one or a combination of focused ion beam, chemical etching, femtosecond laser non-linear ablation with and without chemical assistance, or a process of laser or heat assisted nanoindentation in which a device makes the nanoimpression and a laser or other device is used to transiently melt the surface in which the indentation is to be created.

83. A method and a device as in claims 82 in which all procedures include characterization as in claims 1-7, 10 and 11 and/or claims 47 and 48 that are crucial such that without this characterization the parameters of the procedure used could not be effectively adjusted.

84. A method and a device as in claims 1-7, 10 and 11 and/or claims 47 and 48 in which accurate simulations are combined with unique integrated characterization for the fabrication of other components that can achieve lensing and/or waveguiding including mode convertors, multi lens arrays and other solutions such as microelecromechanical approaches and silicon waveguides in which dopants are used to create waveguides in silicon substrates or femtosecond lasers are used to alter index of refraction in a variety of materials ans where all these lensing or waveguiding solutions would not be able to be achieved with their desired results without the integration of the simulations and the characterization that are part of this invention where only with such simulation and characterization can accurate parameters be defined and no previous invention has realized the criticality of such a closed loop of theoretical simulation, characterization methodologies and diverse production technologies including materials that require standard microelectronic and microelectromechanical fabrication in order to produce defined lensing and/or waveguiding structures that are in glass and/or other materials with a variety of geometries including materials that require standard microelectronic and microelectromechanical fabrication.

85. A method and a device as in claims 1-7, 10 and 11 and/or claims 47 and 48 that integrates near-field optical photoalteration and/or atomic force microscopic lithography as a tool to add Fresnel and/or diffractive optical capabilities to the tip of a fiber or other waveguide either tapered, or untapered, previously lensed or unlensed.

86. A method and a device as in claim 85 in which the fiber can be moved relative to a near-field optical tip through which a laser such as deep UV laser is passed and so permitting the formation of an altered index of refraction at the tip of the appropriate fiber or other waveguide with a resolution that is sufficient to form a Fresnel lens or the formation of a pattern to form a diffractive optical surface.

87. A method and a device as in claim 85 in which a deep UV laser or chemical etching or atomic force lithography or focused ion beam or any other method or combination of these methods that can change the refractive index and or the topography of the core of the fiber or other waveguide with sufficient resolution to be used to produce a Fresnel or diffractive lens and includes theoretical simulation and characterization as in claims 1-7, 10 and 11 as being critical in this fabrication process.

88. A method and a device as in claims 85-87 with and without projection techniques, as used in the semiconductor industry and these can be used to form a pattern onto the fiber or other waveguide core that can alter the index of refraction or topography in a parallel fashion to produce devices that not only provide for focusing but can also provide for dispersion compensation and multifocal and other characteristics such as phase front correction, removal or imposition of birefringence or removal of various aberrations in the resulting lenses.

89. A method and a device as in claims 85-87 in which any optical parameter that can be modulated by Fresnel or diffraction theory or other theories can be achieved, an exemplary case being, the formation of a cylindrical lens with or without tapering in which the two axes have the same foci.

90. A method and a device as in claims 85-89 in which a diffractive optical structure is formed at the end of a fiber or as a stand alone device that uses silver or gold or aluminum or other such metal with an appropriate coating of a dielectric and an aperture appropriately placed that would allow for the manipulation of the light by an interplay between the aperture light transmission and the plasmon characteristics of the device for obtaining unique light manipulation and a critical parameter being the

number of layers of dielectric and the thickness and the number of the metal and the intervening dielectic layers that can be adjusted in order to achieve a match with the wavelength that needs to be manipulated with such parameters varying from a range where no dielectric is included other than the fiber, for a non-free standing film, and only one layer of metal is included to different numbers of dielectric and metal layers with a variety of thicknesses depending on what characteristics are desired.

91. A method and a device as in claims 85-90 in which a critical part is the iterative simulation and characterization tools based on claims 1-7, 10 and 11 and/or claims 47 and 48.

92. A method and a device as in claim 85-91 in which the lenses can be inserted into laser and mechanically polished fibers or other waveguides in order to combine lenses with the beam splitters or other optical components.

93. A method and a device as in claims 85-92 in which any optical parameter that is allowed by Fresnel or diffraction theory or other theories can be achieved.

94. A method and a device as in claims 1-7, 10 and 11 and/or claims 47 and 48 in which all of the lenses can be combined with and without Bragg gratings written into the fiber

95. A method and a device based on a combination of claims 1-93 in which all of the lenses can be combined with and without Bragg gratings written into the fiber.

96. A method and a device as in claims 1-7, 10 and 11 and/or claims 47 and 48 in which the order of the methodologies is chosen so that the lensing is achieved in the fiber without erasing the fiber Bragg grating.

97. A method and a device based on claims 1-95 in which the order of the methodologies is chosen so that the lensing is achieved in the fiber without erasing the fiber Bragg grating.

98. A method and a device as in claims 1-7, 10 and 11 and/or claims 47 and 48 that can produce a solid immersion lens with high index fibers or other such waveguides.

99. A method and a device based on a combination of claims 1-97 that can produce a solid immersion lens with high index fibers or other such waveguides.

100. A method and a device as in claims 98 and/or 99 that can also be transparent in the visible.

101. A method and a device as in claims 100 in which before or after tapering a ball can be formed at the end of the fiber by laser melting and the ball can be subsequently polished by a combination of mechanical and laser polishing to produce a flat mushroom head that can act as a solid immersion lens.

102. A method and a device as in claims 101 in which the ability to combine mechanical and laser polishing is crucial here since the surface of the polished surface has to be made optically of good quality.

103. A method and a device as in claims 101 and/or 102 in where an essential component is for the solid immersion lens to be simulated and characterized as in claims 1-7, 10 and 11 and/or claims 47 and 48 and without which the characteristics of the lens cannot be effectively achieved.

104. A method and a device as in claims 101 and/or 102 in where an essential component is for the solid immersion lens to be simulated and characterized based on a combination of claims 1-91 and without which the characteristics of the lens cannot be effectively achieved.

105. A method and a device as in claims 98-104 which can be placed at the end of a cantilevered fiber to provide the additional sensitivity of an integral atomic force sensor so that the solid immersion lens can be brought in contact or can closely approach a surface and also to sensitively align this lens relative to the illuminating microscope objective.

106. A method and a device as in claims 105 in which the solid immersion lenses can be made with various polishing combinations as in claims so that it could have other geometries such that the flat surface can be polished to a tip and coatings can be applied if so desired.

107. A method and a device as in claim 106 in which the lenses produced can also be combined with Fresnel and diffractive lens characteristics.

108. A method and a device as in claims 1-7, 10 and 11 and/or claims 47 and 48 in which other unique structures such as mushroom or ball lenses can be achieved with or without tapering and lensing with fibers or other waveguides or hollow tapered micropipettes where the subsequent heating with a laser can be used to form a mushroom or ball lens that can be used as a collimator with a handle.

109. A method and a device as in claim 108 in which ball lenses can be used to provide combinations unachievable by other methods such as large fibers or other waveguides that have tapers to concentrate light combined with these and other lenses based on the essential components of simulation and near-field and associated characterization as in claims 1-7, 10 and 11 and/or claims 47 and 48 so that controlled divergence and collimation can be produced.

110. A method and a device as in claim 108 in which ball lenses can be used to provide combinations unachievable by other methods such as large fibers or other waveguides that have tapers to concentrate light combined with these and other lenses based on the essential components of simulation and near-field and associated characterization based on a combination of claims 1-97 so that controlled divergence and collimation can be produced.

111. A method and device as in claims 109 or 110 in which large light sources are concentrated into collimated light sources to enter devices such as fibers with smaller diameters.

112. A method and a device as in claim 111 in which the spot size at the focus is the same as the core diameter at a distance of 50 microns.

113. A method and a device as in claims 108-112 in which ball lenses can be used as one such lens or multiple such lenses.

114. A method and a device as in claim 113 in which an integral fiber lens can be integrated with a ball lens to get a collimated beam of light that can then be used with a second ball lens with or without an aperture or regular lens to get a very small diffraction limited spot size.

115. A method and a device as in claim 114 that allows for the working distance of an integral fiber lens to be extended with such a combination of optics.

116. A method and a device as in claims 1-7, 10 and 11 and/or claims 47 and 48 which use polarization maintaining fibers and multiple pronged structures which can be used either uncoated or metal coated with and without isolation.

117. A method and a device in which tapered micropipettes can be formed of a variety of materials with and without cantilevers for very controlled light concentration beyond the diffraction limit by introducing a silver nitrate solution into an appropriately tapered structure and this structure is inserted into a sugar or other appropriate solution for controlled lengths of time to form a nano seed of silver which then can be grown by electroless methods into a controlled nanoparticle of gold or silver or aluminum or a variety of metals that have plasmon resonances that can be used to concentrate light.

118. A method and a device as in claim 117 in which the solutions in the pipette structure is sugar or chemical with similar properties with a relationship to a metal like silver and the solution out of the pipette structure is silver nitrate.

119. A method and a device as in claim 117 and 118 in which controlled pulling of the pipette out of the surrounding liquid is affected to produce rod or other geometries at the tip of the pipette.

120. A method and a device as in claim 117-119 in which various combinations of illumination, heat and other external perturbations are applied during nanoparticle formation at the tip of these structures and these can alter the characteristics of the particle.

121. A method and a device as in claim 117-120 in which the vessel can be a micropipette of glass or other material in which can be inserted a liquid in the hollow region in order to act as a cooling agent for the nanoparticle during illumination.

122. A method and a device in which a micropipette or similar structure made of any material that is straight or cantilevered and tapered or untapered and can either be coated or uncoated and can either be a force sensor or not a force sensor is filled with a material either by pouring, heating or other means and the material can be a variety of types including dielectric materials such as poly methyl methacrylate or such materials as calcogonides or any other material with a high or low index of refraction and these devices can be used for micro and nano transmission of illumination.

123. A method and a device as in claim 122 with and without an imposed field to act like an optical switch.

124. A method and a device as in claim 122 in which the material filling the pipette or other similar device is under pressure and/or is modulated by wetting so that in a controlled fashion the extent that the liquid will exit the opening and this allows for a small amount of liquid to dry into a nanosphere or other structure whose geometry can be controlled by external means such as illumination, heat or other external means.

125. A method and a device as in claim 124 in which the resulting protruding structure is coated. with another material such as a metal or a dielectric or multiple coatings of metals and dielectrics with different thicknesses.

126. A method and a device as in claim 125 in which the protruding structure is adjusted in its plasmon resonance properties to have such resonances in regions that match the output frequency of one or more laser frequencies.

127. A method and a device as in claim 126 where the structure is made with appropriate means for cooling.

128. A method and a device as in claims 122-127 in which simulation and the near-field optical and other characterization techniques and other characterization techniques as described in claims 1-7, 10 and 11 and/or claims 47 and 48 are crucial in defining the structure, the refractive index and the light modulating properties of such devices.

129. A method and a device in which a tapered or untapered pipette or other hollow device is filled with a material that can harden and before hardening can be made to protrude out of one end of the hollow device or not to protrude or to protrude minimally and the end through which the liquid to be hardened exits or can exit is either placed in a mold or other external means to form at this end an optical element of any desired shape.

130. A method and a device as in claim 129 in which the optical element formed at one end of the filled hollow tube by the mold is a diffractive, Fresnel and/or other such optical element.

131. A method and a device as in claims 129 and 130 in which multiple tubes in multiple molds are used to either automate making multiple devices or making multiple device microarrays.

132. A method and a device as in claims 129 - 131 in which simulation and the near-field optical and other characterization techniques as described in claims 1-7, 10 and 11 and/or claims 47 and 48 are crucial in defining the structure, the refractive index and the light modulating properties of such devices.

133. A method and a device as in claims 129-131 in which only a mold of the optical structure without the hollow tube is used to form a micro lens array and in which simulation and the near-field optical and other characterization techniques as described in claims 1-7, 10 and 11 and/or claims 47 and 48 are crucial in defining the structure, the refractive index and the light modulating properties of such devices.

134. A method and a device as in claims 129-131 in which multiple molds are used without the hollow tube to make a micro lens array or any other means to make micro lenses and/or microlens arrays in which simulation and the near-field optical and other characterization techniques and other characterization techniques as described in claims 1-7, 10 and 11 and/or 47 and 48 are crucial in defining the structure, the refractive index and the light modulating properties of such devices.

135. A method and a device in which a tapered or untapered pipette or other hollow device with multiple channels or with a material that can be altered during processing into multiple channels is filled with a material that can harden with defined index or indices of refraction so that either inside or outside the channels are filled in predefined fashion both in terms of geometry or index of refraction to form optical devices.

136. A method and a device as in claim 135 in which the channels extend through the whole device and there is a surrounding larger channel around all these channels.

136. A method and a device as in claim 135 in which the channels extend through a part of the device and there is a surrounding larger channel around all these channels.

137. A method and a device as in claims 122-136 in which the dimension and index or indices of refraction are adjusted to match the dimension of other standard optical fibers that have to be connected to and this is done in such a manner that the ease of splicing to such fibers is minimized.

138. A method and a device as in claims 1-7, 10 and 11 and/or claims 47 and 48 and/or claims 122-136 in which parameters are chosen (tapered angle and radius of curvature at the end of the fiber) in which a multimode fiber acts as a transmitter or coupler from the multimode to the single mode regime with as high a coupling efficiency as 50 percent or higher and permitting the application of such methodology to a multimode FMSD fiber with a core diameter 50 um and NA 0.2 with a core diameter at the end of the fiber of about 4 um with a focus being reached at a distance of 12 microns from the surface and with a waist diameter of 3.8 microns.

139. A method and a device based on a combination of claims 1-138 in which parameters are chosen (tapered angle and radius of curvature at the end of the fiber) in which a multimode fiber acts as a transmitter or coupler from the multimode to the single mode regime with as high a coupling efficiency as 50 percent or higher and permitting the application of such methodology to a multimode FMSD fiber with a core diameter 50 um and NA 0.2 with a core diameter at the end of the fiber of about 4 um with a focus being reached at a distance of 12 microns from the surface and with a waist diameter of 3.8 microns.

140. A method and a device as in claims 138 or 139 in which the coupling efficiency between multimode lensed fiber and single mode lensed fiber was measured using laser light of 1.5 um.is upto 64%.

141. A method and a device which is simple for the characterization of near-field optical system completely integrated with far-field optical characterization and with atomic force imaging and other scanned probe methods (SPM) that can be used to keep devices under test with the probe fiber in a highly stable contact without pigtailing based on a cylindrical piezo device that has x, y and z motion with feedback to include the probe fiber approaching the device under test with an imposed modulation and the frequency and amplitude of the modulation changes and this is monitored by either the tuning fork or another probe laser which illuminates the fiber directly or through anther fiber.

142. A method and a device as in claim 141 in which the probe fiber is not glued to the tuning fork but rather the tuning fork and the probe fiber are both held in a piezoelectric devices that can bring the probe fiber and the tuning in close proximity to one another until the tuning senses the probe fiber and subsequently the probe fiber is slightly modulated in close proximity to the tuning fork as it approaches the device under test engaging the feedback loop to keep the probe fiber with great stability (upto 0.002 dB) relative to the device under test so that near-field optical profiling, light wave measurements for return loss and other light wave parameters both near and far-field including topography can be measured without pigtailing.

143. A method and a device as in claims 141 and/or 142 in which atomic force or near-field optical or far-field optical signals are used as feedback to maintain the relative position of an optical probe relative to an optical or other device under test without glue or pigtailing.

144. A method and a device as in claims 141-143 in which the device that measures the position of the probe fiber can be a lensed fiber itself as described in this patent or two lensed fibers as can be produced by pulling fibers in a two channel micropipette by the procedures in this patent so that either one lensed fiber or two lensed fibers or two or one fibers without lenses to monitor the probe fiber position and to accurately measure it as it approaches a surface.

145. A method and a device as in claims 144 in which light is sent through the devices onto the probe fiber and then measuring the reflected or the transmitted light so that as the probe fiber frequency, amplitude and/or position changes as it approaches the sample.

146. A method and a device as in claims 141-143 in which it is realized that the worlds of nanopositioning, light wave measurements and imaging can be integrated for optical and other tests and measurements.

147. A method and a device as in claims 141-146 which permits the procedures in claims 1-7, 10 and 11 and including claims 47 and 48 to be automated.

148. A method and a device as in claims 141-146 which permits the procedures in claims 1-147 to be automated.

149. A method and a device as in claim 148 in which all the steps are automated from the theory of simulation of fiber lenses that is included in a program of a computer controlling the automated process to complex fiber handling including pick-up and other handling procedures, tapering under tension and heat, etching, controlled lensing of protrusions, mechanical polishing, laser scribing, and all steps necessary to form the devices including laser and other methods of index of refraction alteration

and in an iterative fashion to include the characterization steps that include near-field and associated characterization.

150. A method and device as in claim 149 in which not only the steps described are included in the automation procedure.

151. A method and a device in which extremely small spot size lenses are produced according to claims 1-7, 10 and 11 and including 47 and 48 in which integral optical fiber lens are used to make a diffraction limited spot size and in which these devices can be cantilevered so that they could fit neatly under the lens of a microscope or can be used as a straight lensed fiber so that a simple scanning integral lensed fiber based confocal (SILC) microscope can be built with the same piezo technology that is used for atomic force microscopes in order to replace complicated beam scanning confocal microscopes with much higher throughput, collection efficiency and resolution than conventional confocal beam scanners.

152. A method and a device in which extremely small spot size lenses are produced based on a combination of claims 1-150 in which integral optical fiber lens are used to make a diffraction limited spot size and in which these devices can be cantilevered so that they could fit neatly under the lens of a microscope or can be used as a straight lensed fiber so that a simple scanning integral lensed fiber based confocal (SILC) microscope can be built with the same piezo technology that is used for atomic force microscopes in order to replace complicated beam scanning confocal microscopes with much higher throughput, collection efficiency and resolution than conventional confocal beam scanners.

153. A method and a device as in claim 151 or 152 in which lens fiber bundles could be used to increase the scanning speed by orders of magnitude.

154. A method and a device in which a confocal microsope is generated in which the fiber is placed in the scanner of an atomic force microscope at the eyepiece or some other port of the microscope and to use the lens of the microscope for final focusing and collection.

155. A method and a device as in claim 154 in which a fiber bundles would be used.

156. A method and a device as in claims 151-155 for mulitphoton microscopy.

157. A method and a device as in claims 151-155 in which the fiber is replaced by a fiber lens in concert with a ball lens and a lens of the microscope on which this combination is installed and the microscope lens being used for both illumination and collection.

158. A method and device as in claims 151-157 in which the fiber lens is connected to a fiber splitter with one channel being the illumination and the other channel being the detector.

159. A method and a device in which a fiber with or without a lens is placed in a piezo tube scanner or other suitable scanning device for scanning so that the fiber is placed accurately relative to the tube lens of a microscope or a ball lens or short focal distance lens that would make a parallel beam and then the objective lens of a microscope or another ball lens would create a spot on the sample.

160. A method and a device as in claim 159 in which the scanner could scan the beam and the lens of the microscope can cause a focused spot.

161. A method and a device as in claims 159 and 160 in which super-resolution and highest throughput is achieved for confocal imaging and where the objective lens of the microscope could collect the light with high efficiency and send it back through the fiber through which the illumination was accomplished.

163. A method and a device as in claims 159-161 in which a fiber splitter could separate the excitation and the detection.

164. A method and a claim as in claims 159-161 in which the illumination channel is separate from the detection channel which can be attached to another optical path and can be a large area detector including a charge coupled device where the scan of the fiber is adjusted to fall on a different pixel of the charge coupled device and the

software for reading the charge coupled device is adjusted to register the fiber position with the pixel of the device.

165. A method and a device as in claims 159 which creates a diffraction limited spot which is important for achieving the highest resolution with a nanometric or other opaque particle blocking the radiation in controlled proximity to the sample using atomic force or other sensing means and the sample is scanned with the appropriate precision to obtain high resolution that is not achievable without this combination of fiber illumination and opaque particle blocking.

166. A method and a device as in claims 160-165 in which the fiber beam scanner and the particle are scanned in unison.

167. A method and a device as in claims 165 and 166 in which the particle is in intermittent contact with the sample and the detection of the illumination is accomplished so that it is in unison with the particle touching and/or is lifted from the surface.

168. A method and a device as in claims 165 and/or 166 in which difference spectra can be recorded between the signal from the sample with the opaque particle in one or another position or between multiple positions.

169. A method and a device as in claims 159-168 in which the sample/objective lens separation can be altered in order to record images from multiple optical planes in focus with the lens.

170. A method and a device as in claims 159-169 in which multiple fibers can be used in the scanner.

171. A method and a device as in claim 159-170 in which multiple opaque particles are used.

172. A method and a device as in claim 165-171 in which the particle that is controlled in its height relative to a surface has a plasmon resonance at the frequency of the illumination and has the ability to enhance a linear or non-linear phenomenon.

173. A method and a device as in claims 159 – 172 that can be used for all mulitphoton microscopies.

174. A method and a device that uses all or a combination of techniques as in claims 159-164 which is applied to data storage applications including magnetic storage in read only or read and write systems.

175. A method and a device that uses all or a combination of techniques as in claims 165-172 which is applied to data storage applications including magnetic storage in read only or read and write systems.

176. A method and a device as in claim 175 for magnetic optical storage where writing of bits can be modulated with a nanometrically controlled opaque particle that can be raised from the surface for heating directly with the illumination or illuminated with higher intensity while the particle is on the surface to transfer heat to the surface for writing, with the position of the particle modulated either by varying the speed in flying head technology or some other active or passive feedback technique with the particle position adjusted either for writing or for high resolution reading.

177. A method and a device in which the high resolution provided by lensed fibers as in claims 1-7, 10 and 11 and/or claims 47 and 48 or combinations of lensed fibers with ball lenses or other optical modulating elements is used for other light scanning devices such as scanners for printers, copiers and other such devices.

178. A method and a device in which the high resolution provided by lensed fibers based on a combination of claims 1-172 is used for other light scanning devices such as scanners for printers, copiers and other such devices.

179. A method and a device as in claim 172 and 173 in which lensed fiber bundles are used.

180 A method and a device as in claims 1-7, 10 and 11 and/or claims 47 and 48 which can be coated with multiple layers of metal isolated with layers of a dielectric such as silicon dioxide with contacts of the metal layers at the tip of the device so that such devices can act also as optical and thermal sensing devices.

181. A method and a device based on the micro or nano optical elements in claims 1-180 which can be coated with multiple layers of metal isolated with layers of a dielectric such as silicon dioxide with contacts of the metal layers at the tip of the device so that such devices can act also as optical and thermal sensing devices.

182. A method and a device based on the micro or nano optical elements in claims 1-181 which can be coated with multiple layers of metal isolated with layers of a dielectric such as silicon dioxide with contacts of the metal layers at the tip of the device so that such devices can act also as optical and thermal sensing devices.

183. A method and a device as in claim 179 –182 in which such devices can be made with force constants that will allow either in their cantilevered or straight form for the devices to act as atomic force sensors for measuring topography and other scanned probe microscopy parameters such as electrical properties.

184. A method and a device employing lensed fibers as in claims 1-7, 10 and 11 and/or claims 47 and 48 in which diffraction limited integral lensed fibers on straight or cantilevered fibers or other waveguides is used in data storage.

185. A method and a device employing lensed fibers based on a combination of claims 1-179 in which diffraction limited integral lensed fibers on straight or cantilevered fibers or other waveguides are used in data storage.

186. A method and a device as in claims 184 or 185 in which the integral lensed fiber is incorporated in a device associated with flying head technology which is particularly suitable to the light weight of integral lensed fibers that need to be held at specific distances from the surface with good control for near-field illumination and detection.

187. A method and a device as in claim 186 in which the fiber has a near-field optical aperture on a lens or has a near-field optical aperture without a lens or has a lens that is of the solid immersion variety.

188. A method and a device which has multiple coatings as in claim 79 including metal coatings separated by dielectric layers to act as an optical and a thermal sensor.

189. A method and a device as in claim 189 which has multiple coatings including metal coatings separated by dielectric layers so that as the device, which is flexible, bends and the resistance of the material between the metal coatings will change allowing surfaces to be approached with feedback based on the alterations in the resistance or other electrical parameters.